Development of a Lead Slowing-Down Spectrometer to Measure the Fission Cross Section of ^{235m}U

R. C. Haight, D. Rochman, S. A. Wender, J. M. O'Donnell, A. Michaudon
LANL, LANSCE-3

D. J. Vieira, A. Kronenberg, R. S. Rundberg, J. Fitzpatrick,
T. Bredeweg, D. W. Efurd, S. Glover, E. Bond, J. B. Wilhelmy
LANL, C-INC

J. A. Becker, K. Moody, Y. Dardenne, D. Shaughnessy
LLNL

T. Ethvignot, T. Granier, M. Petit
CEA/DAM Bruyères-le-Châtel, France

Y. Danon
Rensselaer Polytechnic Institute

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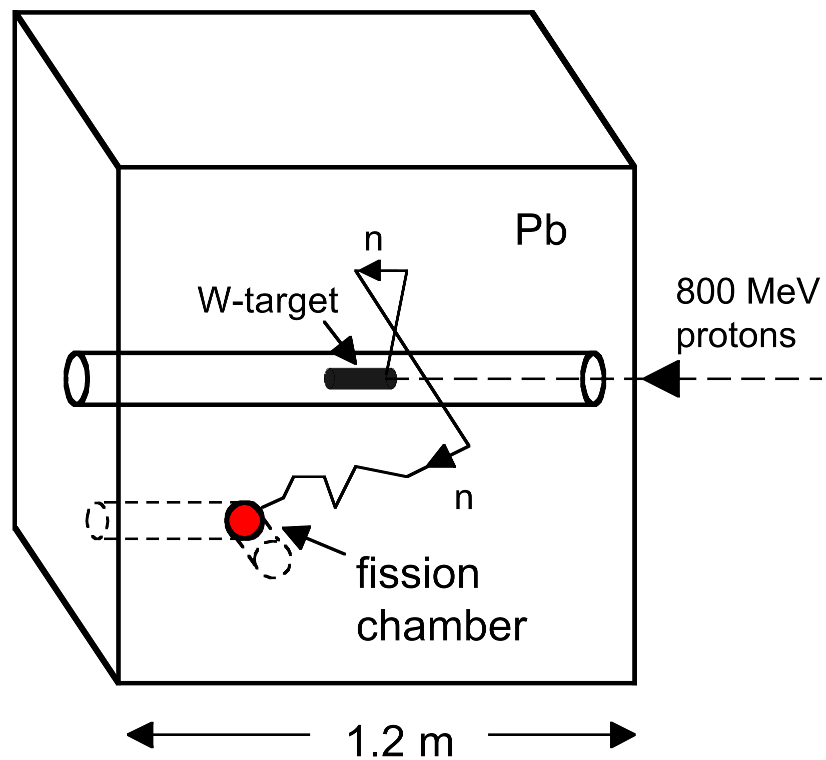
Outline

- Concept
- ^{235m}U(n,f) goal
- Realization
- Preliminary results
- Problems
- Path forward

The LSDS works by "recycling" neutrons

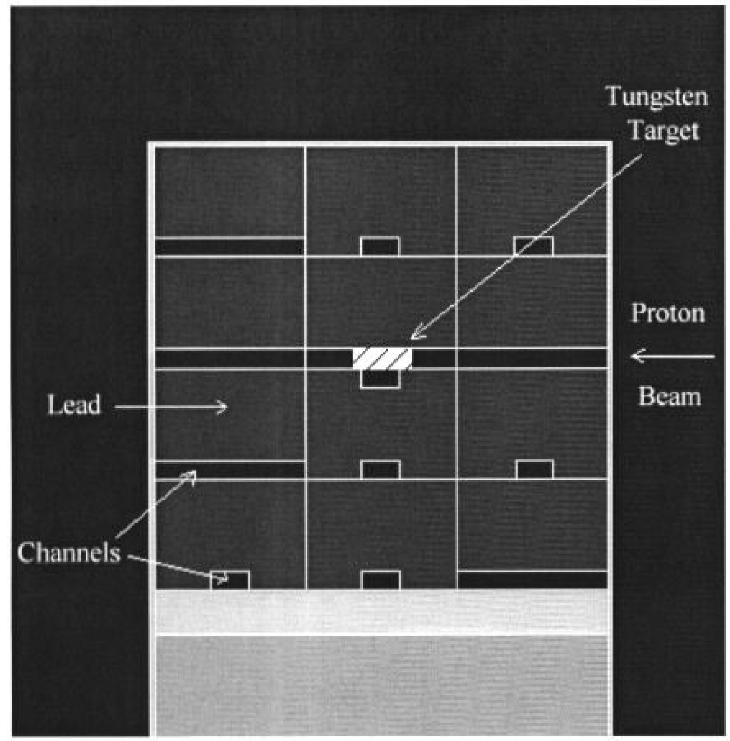
- **Neutron source - pulsed**
- **Big lead cube**
  - **Lead has small absorption cross section**
  - **Lead is a heavy nucleus → small energy loss for neutrons elastically scattered**
  - **Elastic scattering cross section approx. constant with neutron energy**
- **Measure reaction rate (e.g. fission) as a function of time**
- **For $E_n <$ 100 keV**

$$< E_n > = K/(t + t_0)^2$$



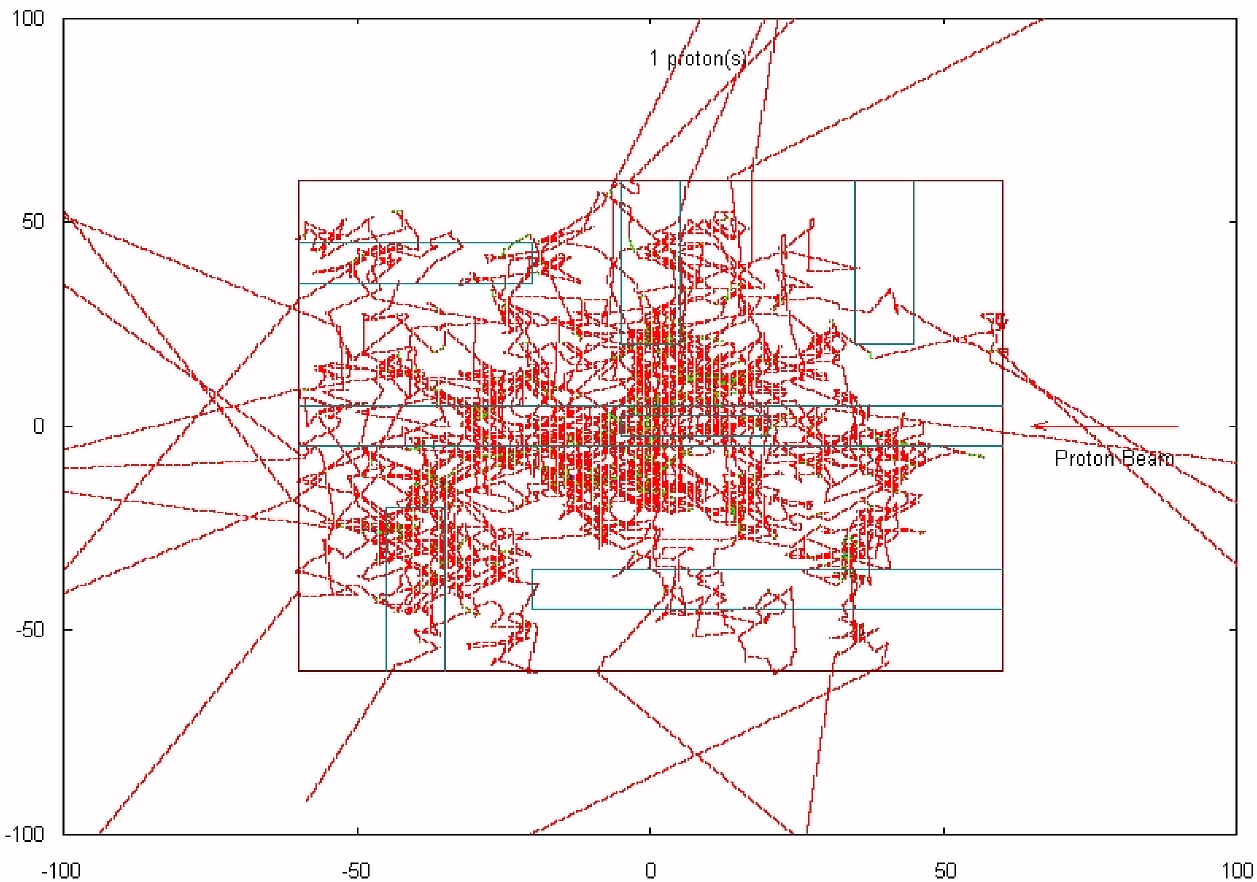
Lead slowing-down spectrometer is a big cube of lead surrounding a pulsed neutron source

- PSR beam to tungsten target in middle of lead cube, 1.2 m on a side
- Cadmium (0.030”) covers outside of cube except for entrance and exit ports.
- $<E_n> \sim 1/(t + to)^{2;}$ $\Delta E_n \sim 30\%$
- E_n ~ thermal to 200 keV
- LARGE increase in neutron flux x 1000)
- Fission samples << 100 ng
- CEA-LANL-LLNL cooperation [lead assembly from CEA]



Vertical View at the Center

Neutron transport is modeled by MCNPX to predict flux and energy resolution



Our approach at LANSCE is to drive the LSDS with a spallation neutron source

- Greatly helps the problem of heat removal from target
  - More neutrons per joule of heating than at electron linacs by factor of ~ 1000
    - » RPI is limited to ~ 700 watts of beam power.
    - » At LANSCE, 1 microAmp and 800 MeV is ~ 800 watts
    - » LANSCE neutron flux greater by factor of ~ 1000
- Fewer gamma rays to confuse detectors
- Idea of Mike Moore et al. CGS 1990 (at Asilomar!)

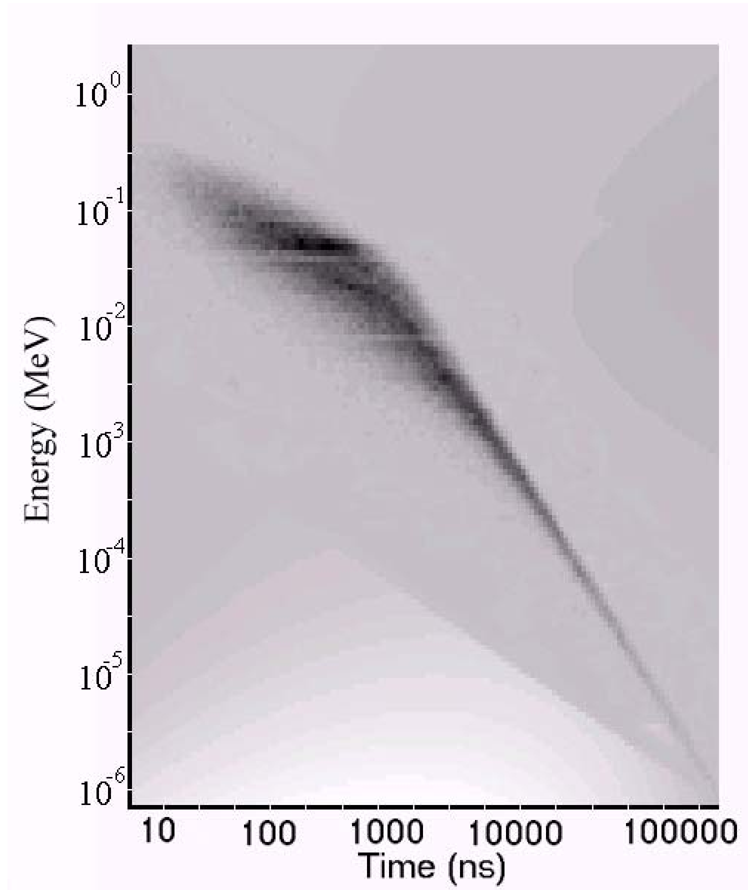
The slowing-down process in lead leads to a "focusing" of the neutron energies in time

Monte Carlo (MCNPX) simulation of the neutron energy distribution as a function of time at a position in the lead volume

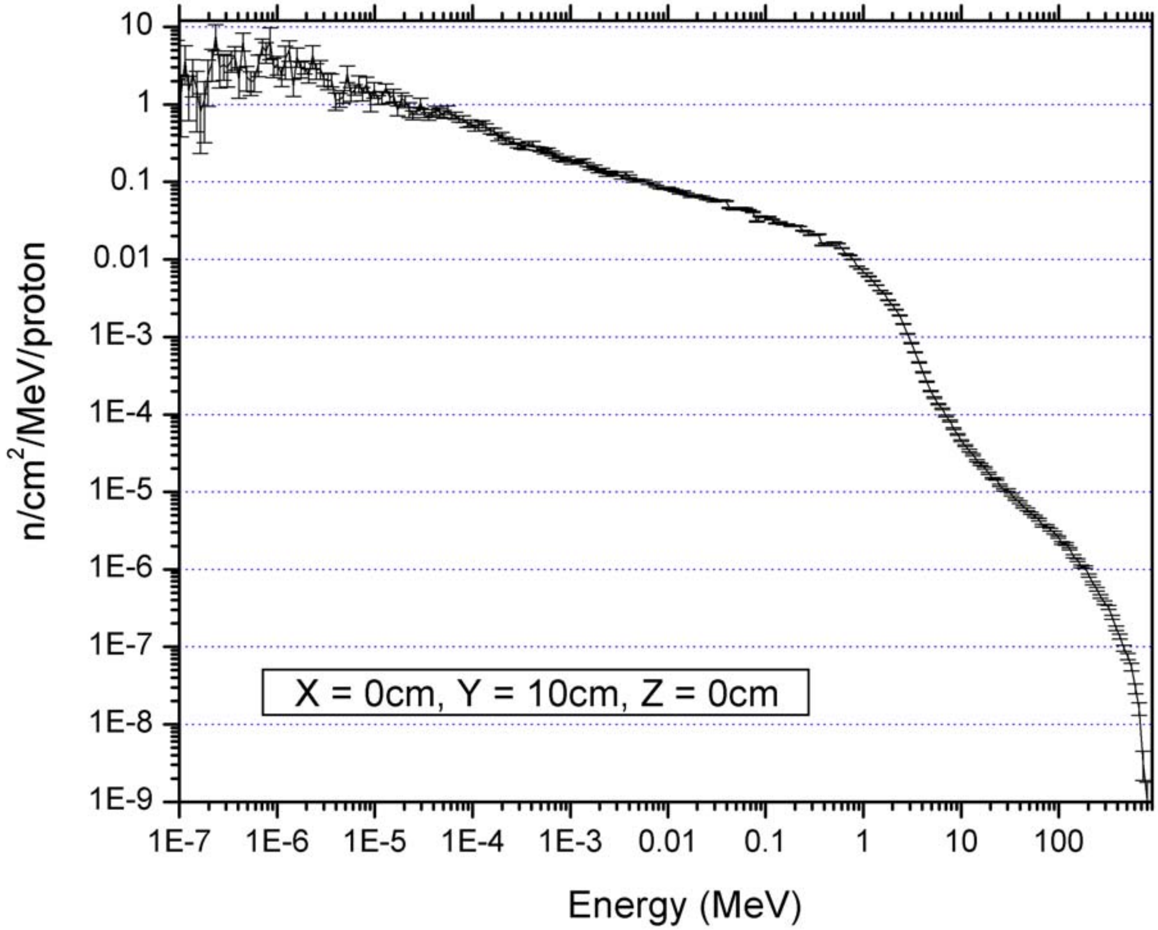
$$\langle E_n \rangle \sim 1/(t + t_o)^{\mathbf{a}}$$

$$\mathbf{a \sim 2}$$

$$\Delta E_n \sim 30\%$$



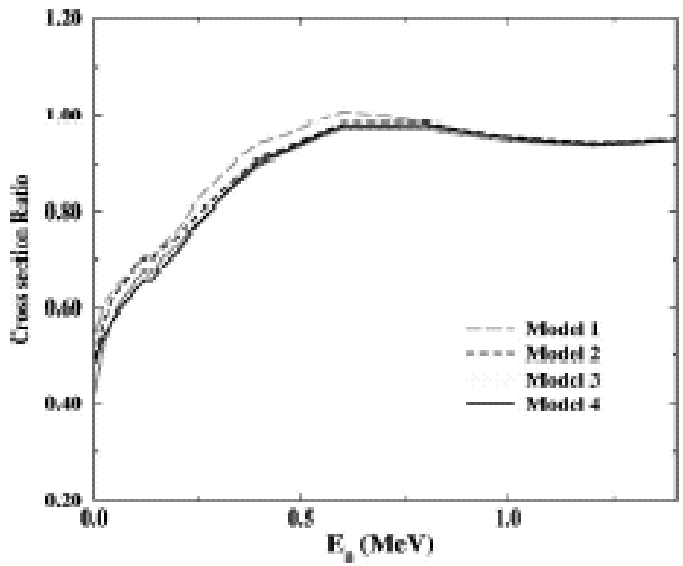
Neutrons expected at a given point in the lead assembly



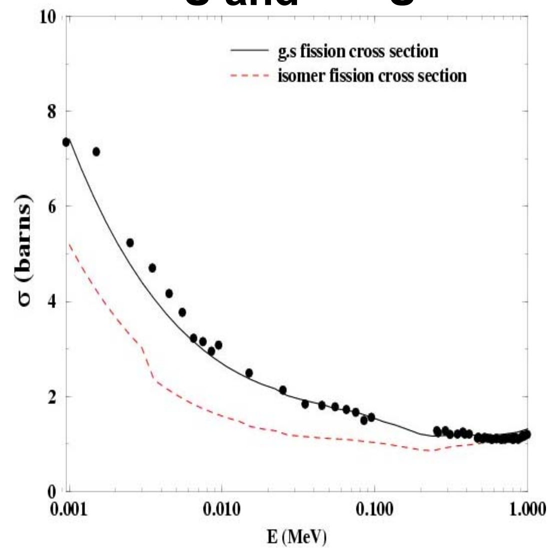
Fission cross sections of ^{235}U and ^{235m}U are predicted to be different below E_n = 500 keV

- **Calculations show that cross section for ^{235m}U is significantly different than for ground state**

Fission cross section ratio: ^{235m}U/ ^{235}U



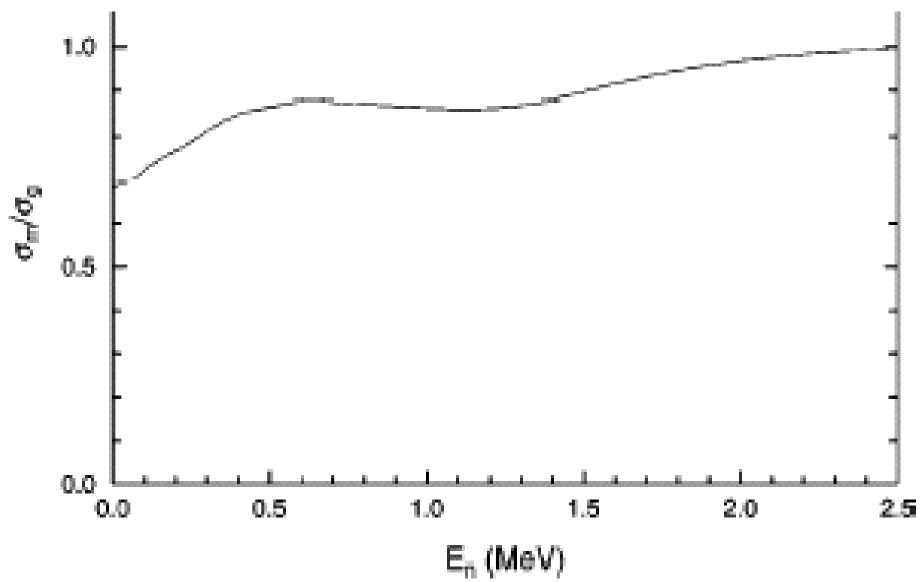
Fission cross section of ^{235}U and ^{235m}U



Ref: Lynn and Hayes, PRC 67, 014607 (2003)

Similar results were found at LLNL

- **Calculations show that cross section for ^{235m}U is significantly different than for ground state**
  - **Similar to LANL analysis .. but somewhat different quantitatively**



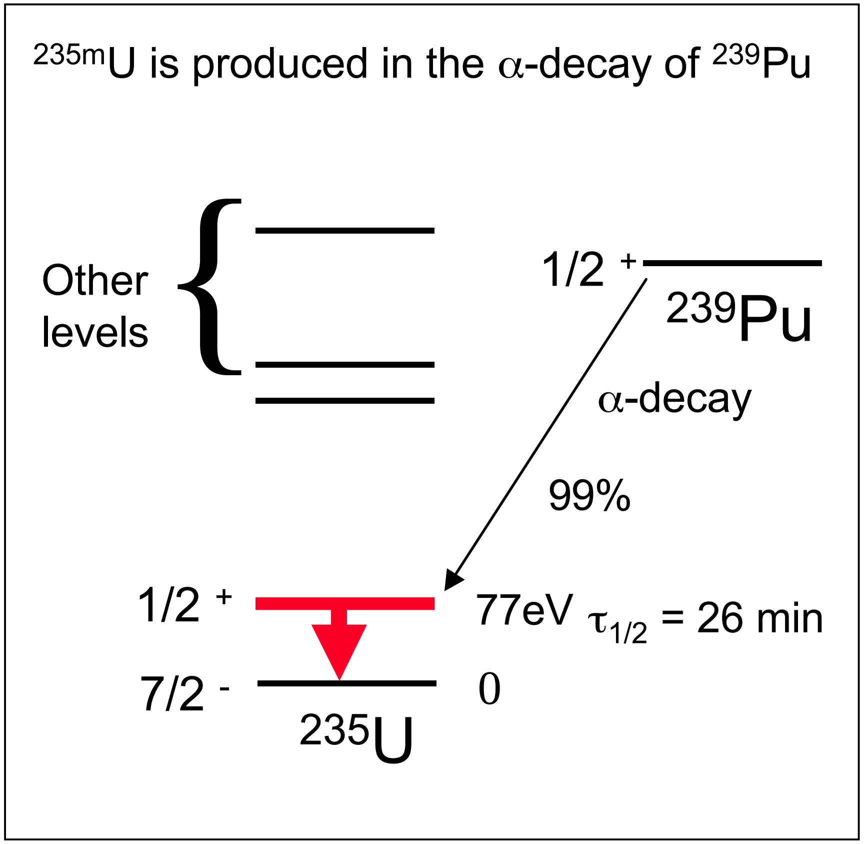
Ref: Younes and Britt, PRC 67, 024610 (2003)

Two theoretical analyses give similar results; experiment can test them.

- Both analyses depend on models
  - both analyses looked at different models – give range of results
- Surrogate reactions have limitations
  - below E_n = 100 keV certainly
  - uncertainties quoted ~ 20% up to 500 keV
- Other information can be obtained from experiment
  - Level densities at different spin-parity at S_n

First excited state of ^{235}U is produced in decay of ^{239}Pu

- ^{235m}U
  - 26 min half-life
  - 77eV
  - Decays by internal conversion
  - 99% of 239Pu decays populate ^{235m}U
  - 5 gm of Pu will produce 10ng of ^{235m}U
- Fast extraction of ^{235m}U will be required
- To measure this small cross section, it is necessary to increase the neutron flux by using a lead-slowing down spectrometer (LSDS)



Our goal is to measure fission cross sections on small actinide samples

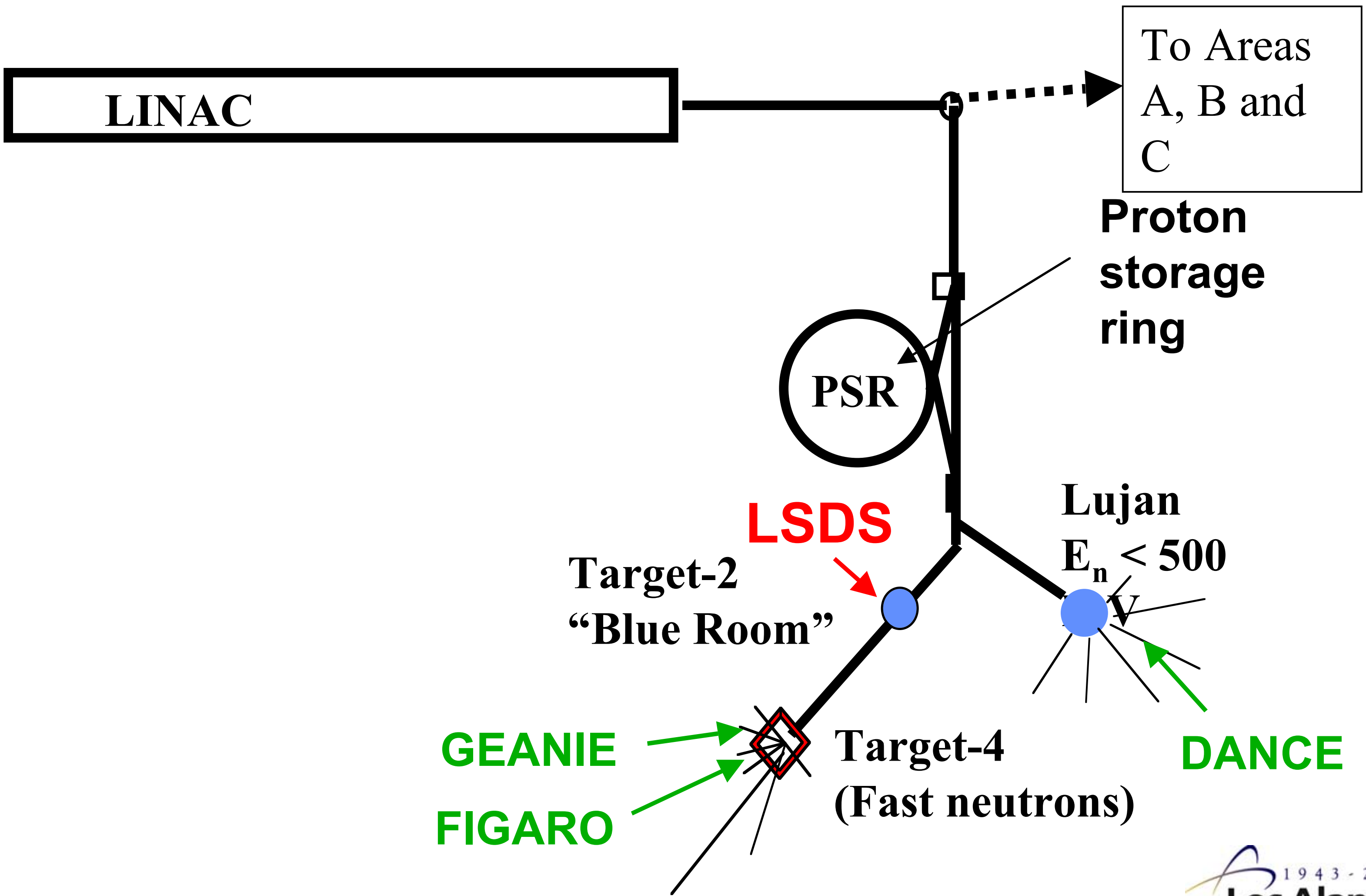
- Reason

LSDS → high neutron flux
→ small samples of actinides (ng)
→ samples of isotopes with short half-lives

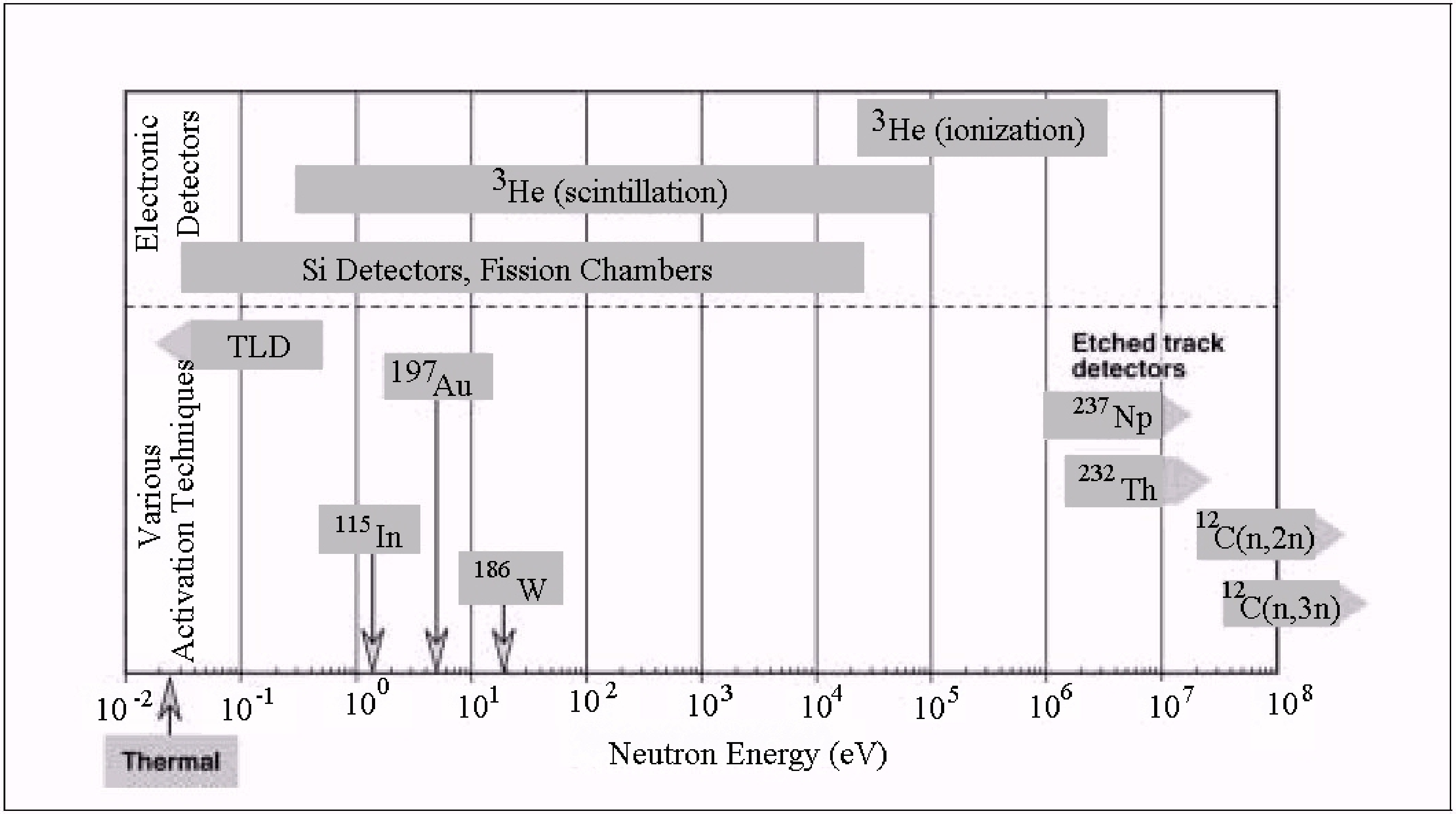
- 1st sample :

^{235m}U → $t_{1/2}$ = 26 min
→ measured at thermal and cold energies (LANL, ILL, Dubna)
→ 5g ^{239}Pu will provide 10 ng of pure ^{235m}U

LSDS is located at Target 2, the “Blue Room” at LANSCE

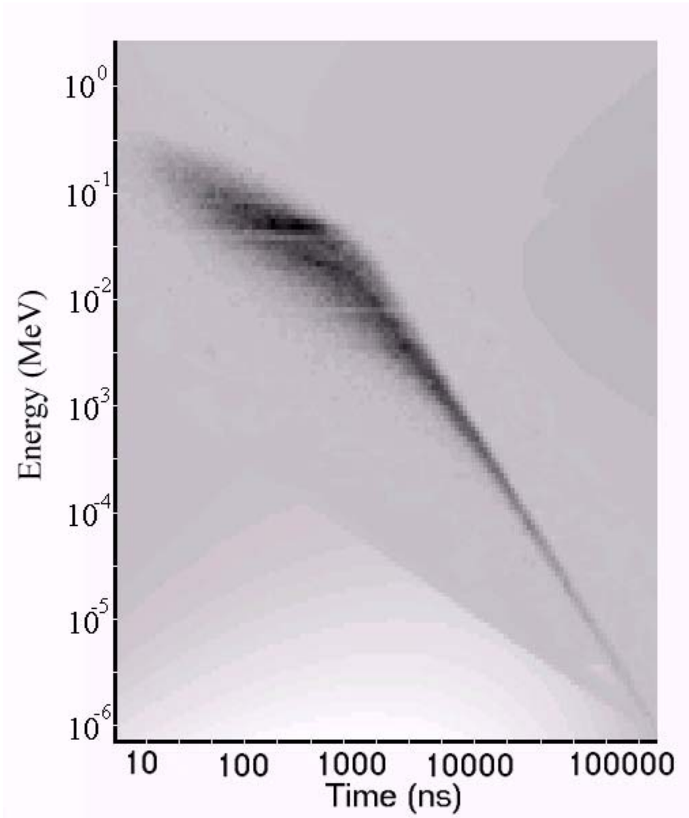


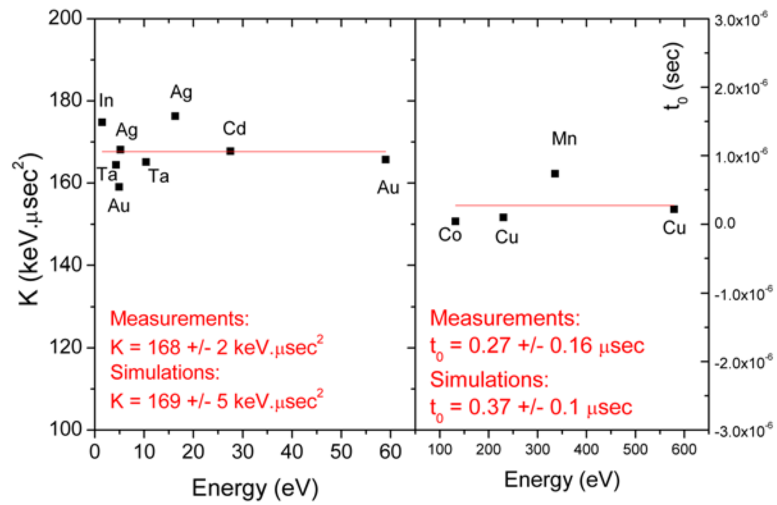
Many types of detectors can be used in the LSDS



→ Characterization of the neutron flux and Energy-Time relation

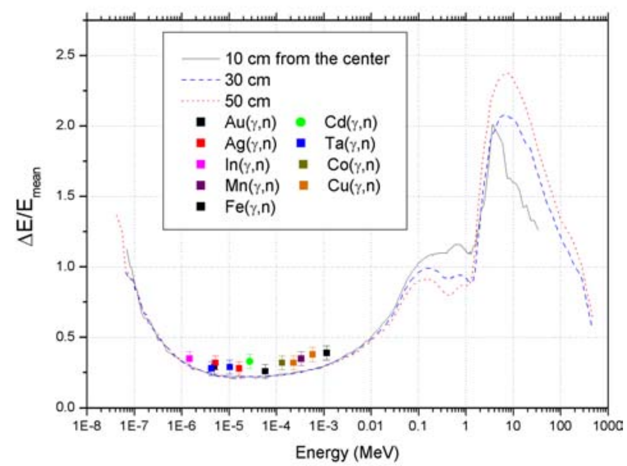
We have characterized the time-energy correlation and measured the resolution in capture resonances





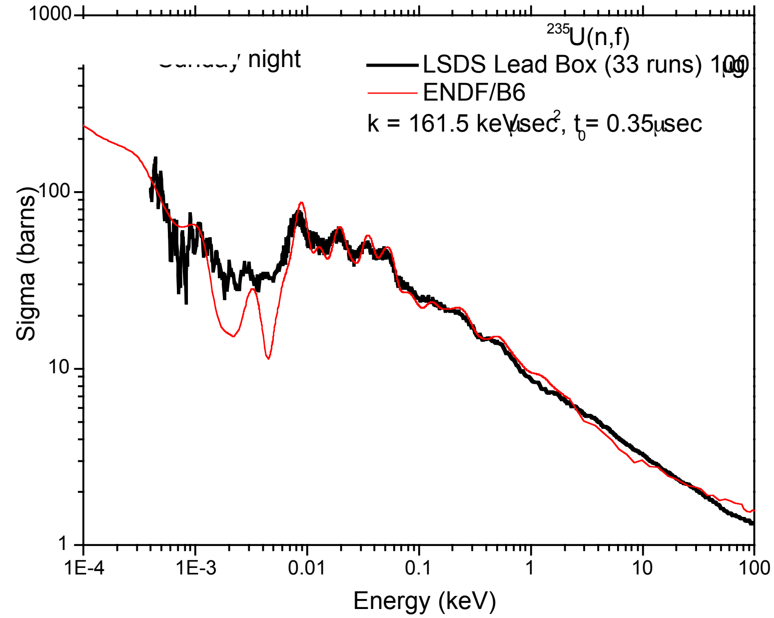
Simulation: $<E_n> = K / (t + to)^2$

with resolution, $\Delta E/E \sim 30\%$



First experiment has measured the cross section for $^{235}U(n,f)$

- ^{235}U deposited on solar cell (silicon diode)
- 100 μg ^{235}U
- proton beam current ~ 7 nA
- ENDF/B-VI cross section convoluted with resolution function



The plan for ^{235m}U(n,f) cross section measurement

Planned running periods

• October 11-15, 2003: Low intensity runs with linac beam; test radiation shielding, activation; test detectors and data acquisition

• December, 2003: Higher intensity runs with linac or PSR beam; test detectors

• February and April, 2004: PSR beam; measure fission cross section of long-lived actinide

• FY 2005: First measurements of ^{235m}U fission cross section

Parallel sample development:

• FY04: Refine Pu-U extraction chemistry; develop electroplated or air-spray-dried sample preparation

• FY04: Install chemistry setup at LANSCE; order and install glove box chemistry setup; draft and implement HCP

• FY05: Test chemistry/sample preparation procedure with small Pu sample

• FY05: Scale up chemistry to 5 g Pu level